ever, the configuration of such electrical stimulation devices is such that, for many users, the electrical stimulation feels uncomfortable. Furthermore, there is a problem in that the discomfort remains even after removing the current.

[0021] [Electrovibrotactile Displays]

[0022] Electrovibrotactile displays will now be described. An electrovibrotactile display is a device that utilizes a skin-attracting effect whereby the skin of a person's hand or fingertips is attracted as a result of applying intermittent voltage to an electrically insulated surface. This physical phenomenon was unexpectedly discovered in 1953 by Mallinckrodt, Hughes et al. (see, for example, E. Mallinckrodt, A. Hughes et al., "Perception by the skin of electrically induced vibrations," Science 118(3062): 277-278, 1953). Mallinckrodt et al. discovered that if a voltage of 110 V is intermittently applied to a metal and a dry fingertip is dragged across the surface of the metal covered with an insulating layer, a rubbery feeling is produced.

[0023] The principle behind this physical phenomenon was analyzed by Mallinckrodt et al. as follows.

[0024] (1) The insulating layer of the dry skin acts as the dielectric material of a condenser with the metal as one capacitor, while the water (i.e. conducting material) contained in the finger constitutes the condenser and acts as another capacitor.

[0025] (2) When an alternating voltage is applied to the condenser, intermittent attractive force is produced between the skin and the metal.

[0026] (3) If the hand is moved while lightly pressing the surface, the friction between the skin and the plate surface periodically varies in magnitude, and the operator experiences the sensation of his or her finger being repeatedly attracted and released.

[0027] Although this phenomenon was discovered in 1953, practical use was not realized until 1970. In 1970, R. M. Strong developed a tactile display based on the above principle (see, for example, R. M. Strong and D. E. Troxel, "An electrotactile display," IEEE Transactions on Man-Machine Systems 11(1): 72-79, 1970). Strong proposed a display made up of an array of many pins covered with a dielectric material. If an intermittent voltage is applied to the pins and a finger is then moved over the pins, a tactile response is felt. More specifically, a distinct sensation of the finger being pulled is felt.

[0028] However, since the fusion of input and sensing technologies was insufficiently realized in proposed tactile displays at the time, the utility value of Strong's proposal was limited. Since the proposed configuration involved the use of a large number of pins, its use in a typical flat display, for example, was unfeasible.

[0029] In 1998, a similar tactile display was proposed by Tang and Beebe (see, for example, H. Tang and D. Beebe, "A microfabricated electrostatic haptic display for persons with visual impairments," IEEE Transactions on Rehabilitation Engineering 6(3): 241-248, 1998). As a result, a thin, durable display was realized by means of microfabrication technology using applied lithography. The underlying principle, however, was identical to Strong's.

[0030] Additionally, an electrovibrotactile display different from the above was proposed by Yamamoto, Nagasawa et al. in 2006 (see, for example, A. Yamamoto, S. Nagasawa et al., "Electrostatic tactile display with thin film slider and its application to tactile telepresentation systems," IEEE Transactions on Visualization and Computer Graphics 12(2): 168-177, 2006). The proposed display is configured as shown in FIG. **1**, wherein a finger **31** moves a slider **20** placed upon a plate electrode **11** having the electrode pattern shown in the figure.

[0031] The slider **20** includes an aluminum layer **21** and an insulating layer **22**. An electrode pattern is formed inside the plate electrode **11** such that + and − voltages are applied in alternation. A periodically varying voltage signal, like that shown by the applied voltage pattern **40** in FIG. **1**, is applied to the electrodes within the plate electrode **11**. As a result of this process, electrostatic force is produced between the conductive material of the slider **20** and the plate electrode **11**. Note that in this configuration, the finger **31** only contacts the insulating layer **22**, and thus a current is not produced. However, the electrode patterning in this configuration makes it difficult to implement in the displays of small devices.

SUMMARY OF THE INVENTION

[0032] As described above, several technologies for providing user interface feedback have been proposed, but a variety of problems still exist, such as unsuitability for compact devices, the discomfort of electric current flowing through a human body, or the limited number of patterns available for use as user interface feedback. In light of such problems, it is desirable to provide a user interface feedback apparatus, a user interface feedback method, and a program applicable to compact devices, for example, and whereby diverse user interface feedback is realized.

[0033] A user interface feedback apparatus in accordance with an embodiment of the present invention includes: an operable element having a two-layer structure made up of a conductor and an insulator; a sensor configured to detect, in the form of user contact information, at least a user contact position with respect to the insulator of the operable element; a processing unit configured to acquire the detected information from the sensor, and determine parameters for an electrical signal to be output to the conductor; and a tactile control module configured to control the frictional force between the insulator and the user by outputting to the conductor an electrical signal regulated by the parameters determined by the processing unit.

[0034] In a user interface feedback apparatus in accordance with another embodiment of the present invention, the processing unit determines voltage values and a frequency for an alternating voltage as the parameters of the electrical signal. The tactile control module then outputs to the conductor an electrical signal made up of an alternating voltage having the voltage values and frequency determined by the processing unit.

[0035] In a user interface feedback apparatus in accordance with another embodiment of the present invention, the sensor acquires and provides to the processing unit position information regarding the user contact site. The processing unit then determines electrical signal parameters in accordance with the position information regarding the user contact site acquired from the sensor.

[0036] A user interface feedback apparatus in accordance with another embodiment of the present invention further includes a display module. The processing unit is configured to determine parameters for the electrical signal according to the relationship between the contact position of the user with respect to the operable element obtained as detected information by the sensor, and an image displayed on the display module.